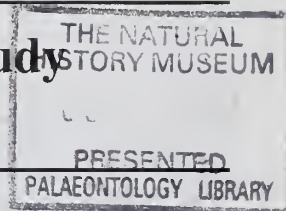


Gough's Cave 1 (Somerset, England): a study of the pelvis and lower limbs



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SYNOPSIS. The lower limb remains of Gough's Cave 1 retain most of the pelvis, both femora, one complete tibia and portions of the other, sections of both fibulae, two tarsals and three metatarsals. They are those of a largely average European Mesolithic young adult male. Overall diaphyseal robusticity is generally similar to that of other Mesolithic specimens, even though the fibula and third metatarsal appear gracile. Musculo-ligamentous attachment areas are generally weakly marked. The proximal femora and the femoral diaphyses exhibit a clear asymmetry, especially in their neck-shaft angles and diaphyseal dimensions, which is accompanied in the pelvis by a greater degree of left iliac lateral flare. These aspects are associated with a pelvis that combines several distinctly male characteristics with an overall pelvic aperture shape which is female.

INTRODUCTION

The Gough's Cave 1 skeleton retains a largely complete pelvis (which has been permanently articulated), both femora very well preserved, most of the right tibia and fibula, portions of the left tibia and fibula, the complete right talus and cuboid, and three complete metatarsals. As such, Gough's Cave 1 retains essentially complete anatomy on at least one side from the L5-S1 articulation to the talocalcaneal articulation, with additional data from the subtalar skeleton.

MATERIALS

The description of the Gough's Cave 1 lower limb remains includes extensive osteometrics (Tables 1–5, 10, 11, 16–21). To evaluate some of these dimensions and the resultant proportions, comparative summary statistics (as available) are included for other European Mesolithic remains. These include remains from the sites of Arene Candide, Los Azules, Bichon, Birmatten, Bottendorf, Riparo Continenza, Culoz, Gramat, Grotte des Enfants, Hoëdic, Holmegård, Koelbjerg, Kosor Glas, Loschbour, Moita do Sebastião, Molar, Mondeval, Muge ($N = 57$), Obercassel, Parabita, Le Peyrat, Le Rastel, Rochereil, Romanelli, Romito, Riparo Tagliente, San Teodoro, Sejro, Téviec, Unseburg, Uzzo, Vaegensø, Vatte di Zambana, and Vervier 1 (Pittard & Sauter, 1946; Graziosi, 1947; Combier & Genet-Varcin, 1959; Barral & Primard, 1962; Genet-Varcin *et al.*, 1963; Patte, 1968; Cremonesi *et al.*, 1972; Ferembach, 1976; Paoli *et al.*, 1980; Holliday, 1995; Holt, 1999; Churchill, pers. comm.). These comparative remains vary in age from terminal Paleolithic to well within the western European Mesolithic, approximately between 12,000 and 6,000 years B.P. They should bracket reasonably well the Gough's Cave 1 remains in age.

The most detailed metrics are available for the Gramat, Hoëdic, Rochereil and Téviec remains, but the other specimens fill out the samples for the more commonly reported measurements (e.g., long bone lengths and diaphyseal diameters). For diaphyseal metrics, the femoral (proximal and midshaft), tibial (proximal) and fibular (midshaft) samples are dominated by the large sample from Muge. Consequently, when the Muge sample is significantly different from the remainder of this 'Mesolithic' sample, summary statistics for it are provided in addition to those for the total sample.

Of the 39 comparative specimens other than those from Muge, 26 are male, 12 are female and 1 has unknown sex. In the Muge femoral sample (the largest sample for the bones providing relevant data), 33 are male and 24 are female. This is therefore a male biased sample, but given the probable male sex of Gough's Cave 1, this is not inappropriate.

METHODS

The majority of the metric comparisons involve traditional osteometrics and associated indices. For these, the values for Gough's Cave 1, the total 'Mesolithic' sample, and the male Mesolithic samples are provided as mean $\pm$ standard deviation in the appropriate text position. Except for Gough's Cave 1, right and left values were averaged prior to computing the sample summary statistics.

In addition, it is appropriate to include cross-sectional geometric parameters (cross-sectional areas and second moments of area) into the description and analysis of the long bone diaphyses of fossil hominids. Consequently, these data are included for Gough's Cave 1 in the description of the femoral and tibial diaphyses (Tables 6, 8, 12, 14). Comparative data are less abundant. They have been generated for the full femoral and tibial diaphyses (five sections each) by S.E. Churchill and myself for most of the Mesolithic remains from Gramat, Hoëdic, Rochereil and Téviec; additional data for the proximal and midshaft femur and midshaft tibia are available from B. Holt (1999) (see Tables 7, 9, 13, 15 for sample sizes).

All of the Gough's Cave 1 and most of the comparative Mesolithic cross sections were reconstructed using transcriptions of the subperiosteal contours and interpolations of the endosteal contours from anterior, posterior, medial and lateral cortical thicknesses. These were done at 20%, 35%, 50%, 65% and 80% of biomechanical length, as preservation permitted. The subperiosteal contours were taken using silicone putty molds [using Cuttersil Putty Plus (Heraeus Kulzer Inc.)] perpendicular to the diaphyseal axis, which were then transcribed onto paper. Cortical thicknesses were measured on antero-posterior and medio-lateral radiographs of the diaphyses, correcting for parallax using the subperiosteal diameters. The endosteal contours were manually interpolated using the cortical thickness rectangle to limit their extent and the subperiosteal contours as a guide. The resultant cross sections were digitized and cross-sectional geometric parameters were computed using a PC-DOS version

(Eschman, 1992) of SLICE (Nagurka & Hayes, 1970). All sections were digitized twice and the results averaged.

From this, six primary measurements were computed. These included total subperiosteal (TA) and cortical (CA) areas, from which medullary area (MA) can be computed, as well as the second moments of area relative to the antero-posterior (I_x) and medio-lateral (I_y) axes, the maximum second moment of area (I_{max}), and the perpendicular to I_{max} (I_{min}). The polar moment of area (J , or I_p), a measure of torsional rigidity and overall strength, is the sum of any two perpendicular second moments of area (usually $I_{max} + I_{min}$, but also equal to $I_x + I_y$).

For a few of the Mesolithic comparative specimens, subperiosteal contour molds were unavailable. For these, the cross-sectional parameters were computed using standard ellipse formulae (Runestad *et al.*, 1993) from the subperiosteal diameters and cortical thicknesses. Given the antero-posterior and medio-lateral orientations of the radiographs, the resultant cross-sectional measures include only cross-sectional areas and antero-posterior (I_x) and medio-lateral (I_y) second moments of area, plus the polar moment of area computed as the sum of I_x and I_y . For these, the resultant computed values were corrected for parallax and non-ellipse shapes of the cross-sections using least squares regressions between the radiographically determined measurements and the cross-sectional values obtained from digitizing the same sections of the other Mesolithic femora or tibiae.

To assess proportions in the Gough's Cave 1 diaphyses using cross-sectional parameters, three shape indices were computed, percent cortical area (%CA: $(CA/TA) \times 100$), I_x/I_y (as a ratio) and I_{max}/I_{min} (also as a ratio). The last two assess diaphyseal shape at the cross section locations, the former with respect to the anatomical

axes and the latter with respect to the axis of maximum bending rigidity. The second is especially appropriate in the proximal femoral diaphysis and along the tibial diaphysis, given varying degrees of torsion in the proximal epiphyses of these bones.

To assess robusticity, and hence to scale the cross sectional parameters to appropriate body size and beam characteristics (Ruff *et al.*, 1993), cortical areas (as a reflection of axial loading levels) and polar moments of area (as a measure of resistance to bending and torsional loads) should be plotted against appropriate powers of long bone lengths adjusted for variance in body laterality and crural indices. Cortical areas should scale to body mass, which is proportional to femoral length cubed (Ruff *et al.*, 1993). Polar moments of area should scale to body mass times beam length, all raised to the four-thirds power (Ruff *et al.*, 1993). In other words, for the femur $J \propto (FL^3 \times FL)^{4/3} = FL^{16/3}$ and for the tibia $J \propto (FL^3 \times TL)^{4/3} = FL^4 \times TL^{4/3}$.

However, given the apparently similar degrees of body laterality and crural indices across these European terminal Upper Paleolithic and Mesolithic samples, as is expected by theoretical considerations (Ruff, 1991) and supported by current data (Holliday, 1995; Holliday & Churchill, 2003), it is appropriate to simply scale logged cortical areas and logged polar moments of area against logged bone length. Since this approach avoids determining the actual allometric scaling coefficient for each of these bones, it is employed here.

In addition, even though comparative data are not available, metatarsal midshaft cross-sectional geometric measures are provided (Table 20). They were computed from radiographically determined subperiosteal diameters and cortical thicknesses using ellipse formulae (Runestad *et al.*, 1993) after the radiographic measurements were corrected for parallax using the osteometrically determined diaphyseal diameters.

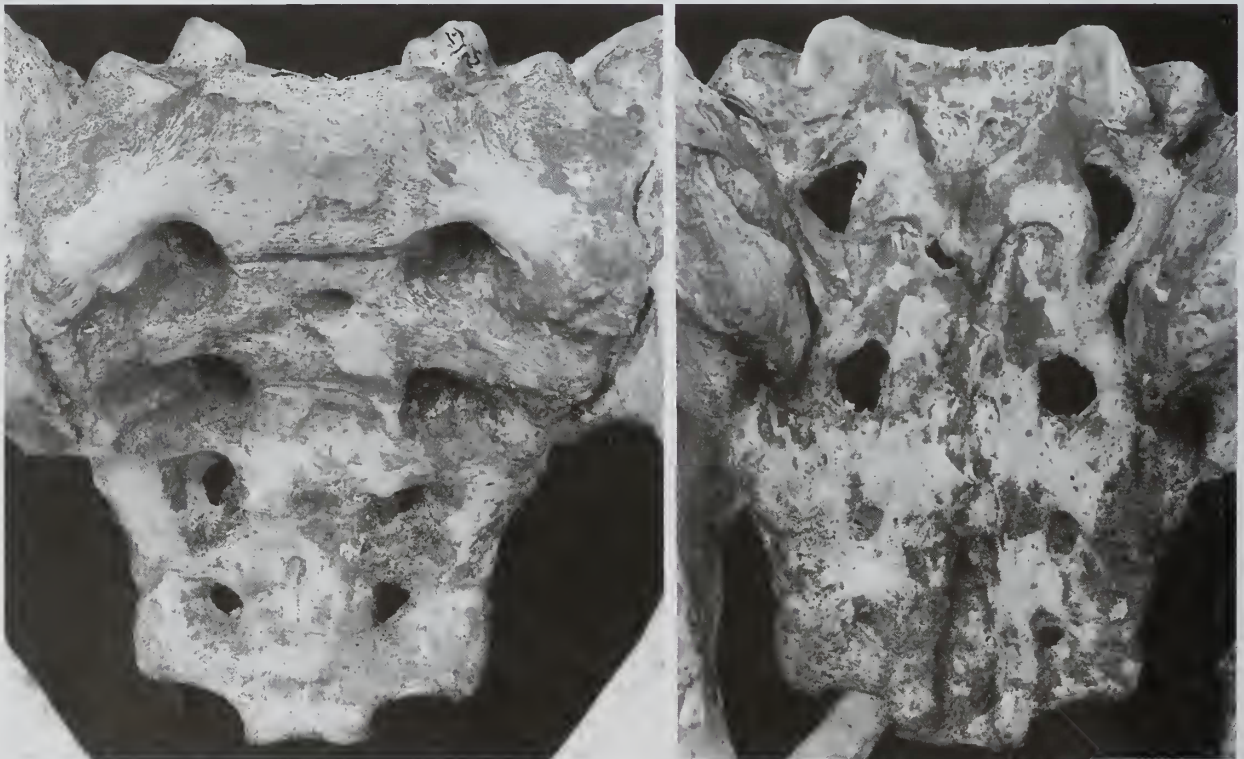


Fig. 1 Ventral (left) and dorsal (right) views of the sacrum; $\times 0.75$.

PELVIC REMAINS

Inventory

The pelvis is conserved fully articulated, with the two coxal bones in articulation with the sacrum and with each other at the pubic symphysis (Figs 1–5). As a result, overall dimensions and proportions are readily ascertainable, but the configurations of the sacroiliac and pubic symphyseal surfaces are not observable. In addition, there is a bolt transversely through the sacroiliac articulations, the S2 and the dorsal ilia which maintains the pelvis in articulation. It is only apparent on the external ilia just dorso-cranial of the dorsal greater sciatic notches.

Despite minor abrasion to several of the margins, there is no apparent distortion to any of these bones, and adhering matrix is thin and scattered. This makes morphological observations on them highly reliable.

Sacrum. The sacrum is largely complete from the cranial S1 to the caudal S5, with minor abrasion to several of the edges. The primary areas of abrasion are across the sacral promontory producing a rounded margin, and on most of the S1 cranial disk surface and the cranial surfaces of the alae. There is also minor surface bone loss along the edges of the sacro-iliac articulations, but it is largely obscured by their articulations with the ilia. There is also a rounded hole dorso-ventrally through the S2 body, the result of a bolt placed through it for the previous mounting of the articulated skeleton in the Gough's Cave Museum.

Right Coxal Bone (No. 1.1/23). The right coxal bone is essentially intact. There is abrasion to the ventro-caudal ischio-pubic ramus margin just ventral of the ischial tuberosity, to the internal margin of the mid iliac crest, and along the superior auricular margin extending on to the dorsal arcuate line. In addition, the middle of the iliac fossa has an area of adhering matrix and a small hole (maximum diameter: 6.5mm) in the middle of that area. All of the iliac crest is present, even though it is partially fused.

Left Coxal Bone (No. 1.1/24). The left coxal bone is similarly intact without distortion. It shares the same abrasion to the ventro-caudal margin of the ischio-pubic ramus just ventral of the ischial tuberosity and to the cranial margin of the auricular surface and adjacent arcuate line. In addition, there is a notch of bone missing from the ventral ilium just below the anterior superior iliac spine, and there is a large hole (31.8mm dorso-ventral and 23.0mm cranio-caudal) in the middle of the iliac fossa. The iliac crest is present ventrally, but it was (at least partially) unfused between the iliac pillar and the iliac tuberosity and is absent from that portion of the ilium.

Pelvic Morphology

Sacrum (Table 1; Fig. 1). The Gough's Cave 1 sacrum retains five clear sacral vertebrae. In this they follow the pattern of the majority of recent humans (Schultz, 1930). Despite damage in the regions of the auricular surfaces, it appears that the lateral portions of the sacrum and their dorsal neural arches were fully fused at the time of death. However, the bodies remain largely separate across their ventral margins. The degree of fusion of the sacral bodies and the pattern of fusion (from caudal to cranial) primarily reflects the young adult age of the individual and not an unusual pattern or degree of sacral fusion.

The ventral length of the Gough's Cave 1 sacrum of ca.123.7mm is large for a recent human (Radlauer, 1908). In combination with a mean femoral bicondylar length of 436.0mm, it provides a length

Table 1 Osteometrics of the Gough's Cave 1 sacrum.

Ventral height chord (M-2) ¹	(123.7)
Ventral height arc (M-1)	(131.5)
Ventral S1 height chord ²	(32.2)
Ventral S2 height chord	30.2
Ventral S3 height chord	25.9
Ventral S4 height chord	21.8
Ventral S5 height chord	19.5
Dorsal height chord (M-3)	124.7
Antero-cranial breadth (M-5)	(110.0)
Mid sacral breadth (M-9)	83.0
Base dorso-ventral diameter (M-18)	(29.0)
Base transverse diameter (M-19)	46.2
Base sagittal angle ³	81°
Base/S1 sagittal angle ⁴	60°
Canal dorso-ventral diameter (M-16)	17.6
Canal transverse diameter (M-17)	30.6

¹ (M-xx) refers to the equivalent measurement in R. Martin's *Lehrbuch der Anthropologie* (see Bräuer, 1988).

² Cranio-caudal distance between the cranial and caudal margins of each ventral body.

³ The angle, in the median sagittal plane, between the tangent to the S1 vertebral disk surface and the ventral height chord from S1 to S5.

⁴ The angle, in the median sagittal plane, between the tangent to the S1 vertebral disk surface and the ventral surface of S1.

index of ca.28.4. This value high for a recent human sample (Warren, 1897; Trinkaus, 1983) but it is only slightly above a Mesolithic sample mean (27.6 ± 2.2 , $N = 14$) and very close to the mean of a Mesolithic male sample (28.0 ± 2.2 , $N = 11$).

The maximum antero-cranial breadth of the Gough's Cave 1 sacrum (ca.110.0mm) is moderate compared to other Mesolithic remains, and it provides an index against ventral height of 88.9. This value is only slightly below that of a highly variable Mesolithic sample (91.4 ± 8.9 , $N = 16$) and removing the three females from the sample moves the mean close to the Gough's Cave 1 value (Mesolithic males: 89.8 ± 8.4 , $N = 13$).

The sacrum presents a modest degree of ventral concavity, as is indicated by an index of the ventral chord to the ventral arc of ca.94.1. This index is well above the mean of a Euroamerican male sample [85.8 ± 4.7 , $N = 50$ (Tague, 1989)]. However, it is quite close to means of 93.3 for both Mesolithic samples (pooled sex sample: ± 2.5 , $N = 9$; males: ± 2.6 , $N = 8$). Most of the curvature present is in the vicinity of S4, with only a slight concavity cranial of the S3/S4 articulation.

The sacral foramina are all present and prominent. They are slightly larger on the left side, primarily in cranio-caudal height, but present no unusual features.

The cranial surface of the S1 is notable for the degree of caudal slope of the alae, from the lateral margins of the S1 body to the cranial margins of the auricular surfaces (or their estimated positions given damage). The degree of downward slope is indicated by a cranio-caudal distance of 21.0mm between the promontory and a line between the intersections of the arcuate lines and the auricular surfaces. In a parallel way, the S5 body extends caudally from its lateral portions, down to a clearly delimited body surface for the Cx1 articulation.

The sacral hiatus extends cranially to the level of the S3/S4 intervertebral body articulation. In two recent human samples, Euroamericans and Afroamericans, about a third of the individuals have the hiatus extend cranially to the cranial S4 or above [34.3%, $N = 519$ and 30.4%, $N = 694$ respectively (Trotter & Lanier, 1945)], making this pattern in Gough's Cave 1 relatively common.

Ilia (Table 2; Fig. 2). The Gough's Cave 1 ilia present relatively smooth surfaces but with generally clear markings for the various

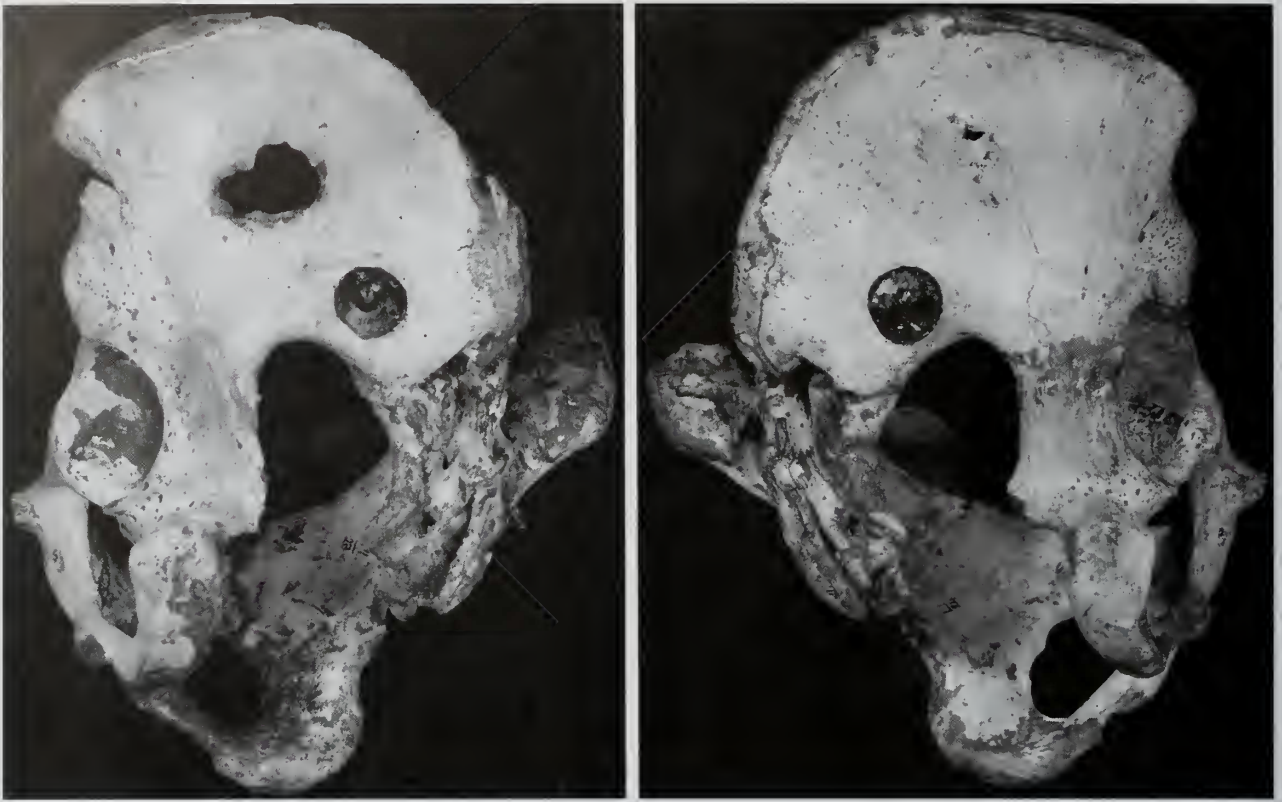


Fig. 2 Dorso-lateral views of the left and right ilia and ischia, with the caudal sacrum; $\times 0.44$.

Table 2 Osteometrics of the Gough's Cave 1 ilia, acetabulae and greater sciatic notches.

	Right; 1.1/23	Left; 1.1/24
Iliac blade height (M-10)	100.0	100.9
Iliac blade depth (M-11)	9.2	(8.0)
Superior iliac breadth (M-12)	166.0	164.5
Inferior iliac breadth ¹	119.4	(113.0)
Arcuate line chord ²	—	59.0
Arcuate line subtense ³	—	3.5
Acetabular height ⁴	53.8	53.5
Acetabular depth ⁵	24.0	26.1
Acetabulo-sciatic breadth ⁶	35.6	35.2
Greater sciatic notch height ⁷	54.6	(50.0)
Greater sciatic notch breadth ⁸	40.9	42.2

¹ Maximum direct length around the anterior inferior iliac spine and the posterior inferior iliac spine.

² Anterior margin of the auricular surface to the point on the arcuate line where a line, perpendicular to the arcuate line and passing through the depth of the psoas groove below the anterior inferior iliac spine, meets the arcuate line (Ruff, 1995).

³ Maximum subtense from the arcuate line chord to the arcuate line.

⁴ Acetabular margin height from the margin adjacent to the anterior inferior iliac spine to the most distant point on the inferior acetabulum, measuring only on the subchondral bone of the acetabulum proper.

⁵ Maximum depth from the height chord to the subchondral bone.

⁶ Minimum distance from the postero-lateral margin of the acetabulum to the ischial margin of the greater sciatic notch.

⁷ Direct distance from the middle of the ischial spine to the middle of the posterior inferior iliac spine.

⁸ Direct distance from the middle of the posterior inferior iliac spine to the posterior ischial margin of the greater sciatic notch, taken perpendicular to the ischial margin between the notch itself and the ischial spine.

muscular attachments. Externally, the gluteal abductor surfaces show little relief. One can perceive a *M. gluteus minimus* line curving from the iliac crest to the greater sciatic notch region, and there is smooth vertical ridging on the surface dorsal of that line. Internally, there is erosion on both sides but the preserved areas are evenly concave and smooth. The iliac portions of the arcuate lines are rounded angles from the acetabular area to the auricular surfaces.

The cranial surfaces of the greater sciatic notches are smooth bilaterally. The right one, however, presents a prominent pre-auricular sulcus, with some rugosity but mostly resorptive bone. The well-preserved left one, in contrast, is smooth with no trace of a pre-auricular sulcus.

The iliac crest is moderately developed where it is preserved, with minimal rugosity. Similarly, the anterior superior iliac spine is modest in its development, producing only a small concavity in lateral view between it and the anterior inferior iliac spine (at least on the right side, where the bone is intact). The anterior inferior iliac spines are prominent and thick, but there is no lateral rotation of the spines or internal concavity to them. Yet, they are accompanied by a distinct sulcus between them and the acetabular margin, ca. 1.5mm wide on each side. The attachment area for the long head of *M. rectus femoris* is evident but not accompanied by marked rugosity or surface bone resorption.

Ischia (Table 3; Figs 2, 3). The ischial tuberosities are generally smooth with prominent proximal depressions for the insertions of *Mm. semimembranosus*. They are clearly differentiated from their adjacent acetabular margins as well as from the ventro-lateral surface



Fig. 3 Ventro-lateral view of the right ischiopubic region, with ventro-medial view of the left ischiopubic ramus; $\times 0.6$.

Table 3 Osteometrics of the Gough's Cave 1 ischio-pubic regions.

Pubic length ¹	90.4	90.2
Acetabulo-symphysal length ²	65.5	70.1
Ventral pubic ramus thickness ³	11.0	11.4
Symphysal height (M-18)	41.7	42.4
Symphysal breadth (M-19)	20.2	21.7
Symphysal body breadth ⁴	23.7	24.0
Obturator foramen length (M-20)	62.2	61.5
Obturator foramen breadth (M-21)	36.6	37.2
Ischial length ⁵	87.0	86.8
Ischial tuberosity breadth ⁶	27.2	28.5
Ischio-pubic ramus height ⁷	—	16.2
Ischio-pubic ramus thickness ⁸	—	8.2
Ischio-pubic chord ⁹	102.8	(102.0)
Arcuate line chord ¹⁰	—	125.0

¹ Direct distance from the middle of the acetabulum to the medial symphysis.
² Direct distance from the medial symphysis to the nearest point on the acetabular margin (McCown & Keith, 1939).
³ Minimum thickness from the sulcus for the obturator vessels and nerve to the middle of the cranial surface of the superior pubic ramus (Trinkaus, 1983).
⁴ Minimum distance from the middle of the pubic symphysis to the adjacent obturator foramen margin.
⁵ Mid-acetabular point on the superior margin of the acetabular notch to the furthest point on the ischial tuberosity.
⁶ Maximum breadth of the muscle attachment area on the tuberosity.
⁷ Minimum dimension of the ramus, measured in an supero-dorsal to infero-ventral direction, parallel to the ventro-lateral surface of the ramus.
⁸ Minimum dimension of the ramus, measured perpendicular to the ramus height.
⁹ Direct distance between the dorsal end of the ischial spine and the inferior margin of the pubic symphysis [Tague (1989) measurement MD].
¹⁰ Direct distance along the arcuate line from where it meets the anterior margin of the auricular surface to where it meets the pubic symphysis [Tague (1989) measurement KO].

of the ischium along the obturator foramen. There is a slight development of ridged bone between the dorso-cranial corners of the tuberosities and the ischial spines for the bursae of each *Mm. obturator internus*, especially on the left side. However, the sulci for each *Mm. obturator internus* do not impinge on the tuberosities, as in many recent and Late Pleistocene humans (Trinkaus, 1996). This is accompanied by a strong lateral rotation of the tuberosities, such that their primary muscular surfaces are almost in the same planes as the external ilia.

The tips of the ischial spines are absent, but they appear to have been curved inwards and moderately robust.

Pubic bones (Table 3; Fig. 3). The pubic bones present prominent pubic tubercles for the inguinal ligaments, accompanied by clear, angled but not cresting pectineal lines, extending from adjacent to the acetabulae to the symphysis. The ventral margins of the superior pubic rami are moderately thick (11.0 and 11.4 mm), and end ventrally in rounded but downwardly curved margins. The symphyseal bodies are narrow.

The internal surfaces of the symphyseal bodies and the ischio-pubic rami are smooth with only a hint of musculo-ligamentous attachments, but the cranial two-thirds of the external ischio-pubic rami have strong muscular markings and are ventrally flared.

Acetabulae (Table 2). There is little of note on the acetabulae except for a large pit on each of the subchondral bone surfaces in the middle of the weight bearing portion (the middle of the iliac portion between the anterior inferior iliac spine and the iliac pillar). The details of it are obscured on the left side by adhering matrix, but on the right side it is accompanied by a large vascular groove between it and the acetabular notch plus a smaller pit 19.0mm ventral of it immediately below the anterior inferior iliac spine.

Pelvis as a Whole (Table 4; Figs 4, 5). The articulated Gough's Cave 1 pelvis presents a largely symmetrical outline. The only real right-to-left contrast is in the degree of iliac flare, in which the left ilium is more laterally and less vertically oriented. The only other visual difference, the apparently more open sub-pubic angle on the right side, is the product of postmortem abrasion to the right ischio-pubic ramus.

The completeness of the Gough's Cave 1 pelvis permits comparisons of some 'obstetric' dimensions to those of at least recent human samples (Tague, 1989). In particular, comparisons are made to Euroamerican males, matching sex and approximate geographic origin. The pelvic funneling index of Gough's Cave 1 (outlet (bi-tuberous) breadth vs. inlet breadth: 79.2) is essentially the same as the mean of the recent Euroamerican male sample (78.8 ± 7.9 , $N = 50$), and similar to the means of Afroamerican and Amerindian male samples and well below the means of similar female samples (Tague, 1989). However, the inlet, midplane and outlet shape indices (dorso-ventral vs. transverse diameter) of Gough's Cave 1 (100.0, 115.0 and 104.2 respectively) contrast with those of the Euroamerican male sample (79.0 ± 7.9 , 133.4 ± 6.9 , 111.1 ± 14.1 ; $N = 50$). In this, Gough's Cave 1 has a much rounder pelvic inlet, one which is hyperfemale. Its midplane index is low for either males or females, and its outlet proportions are between the means of the Euroamerican male and female samples. These proportions therefore combine with several other aspects of its pelvic morphology in indicating a relatively female-like but male pelvis.

Table 4 Osteometrics of the Gough's Cave 1 articulated pelvis.

Pelvic inlet antero-posterior diameter (M-23)	125.0
Pelvic midplane antero-posterior diameter ¹	112.0
Pelvic outlet antero-posterior diameter ²	103.2
Bi-iliac breadth (M-2)	274.0
Pelvic inlet transverse breadth (M-24)	125.0
Articular bi-acetabular breadth (M-7)	126.0
Minimum bi-acetabular breadth (M-7(1))	115.0
Bi-spinous breadth (M-8)	97.4
Bi-tuberous (outlet) breadth ³	99.0
Sub-pubic angle (M-33)	64°

¹ Direct distance from transverse ventral line between fourth and fifth sacral vertebral bodies to dorsomedial margin of the inferior pubic symphysis [Tague (1989) measurement CD].
² Direct distance from the ventral apex of the fifth sacral vertebra to the dorso-medial margin of the inferior pubic symphysis [Tague (1989) measurement DE].
³ Minimum distance between the two ischial tuberosities.

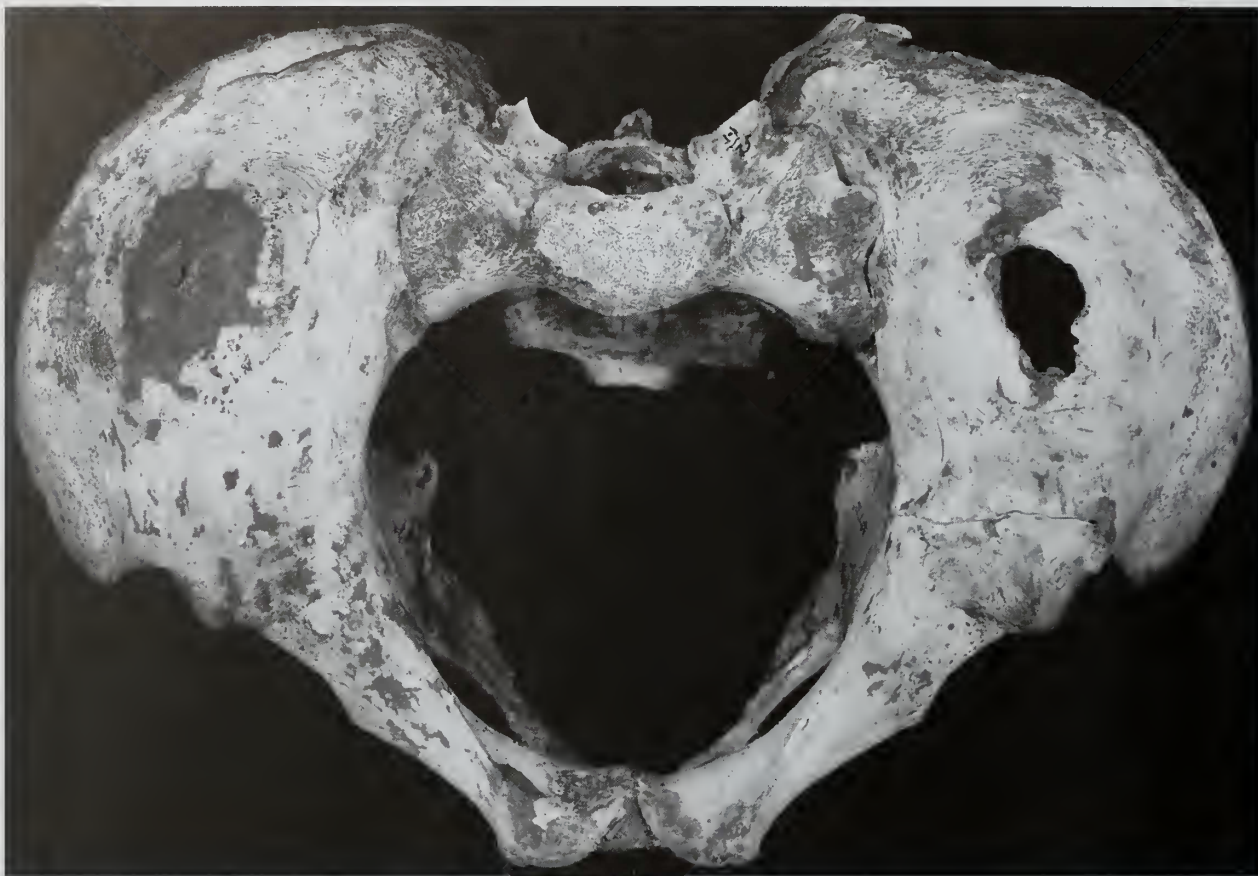


Fig. 4 Cranial view of the articulated Gough's Cave 1 pelvis; $\times 0.6$.

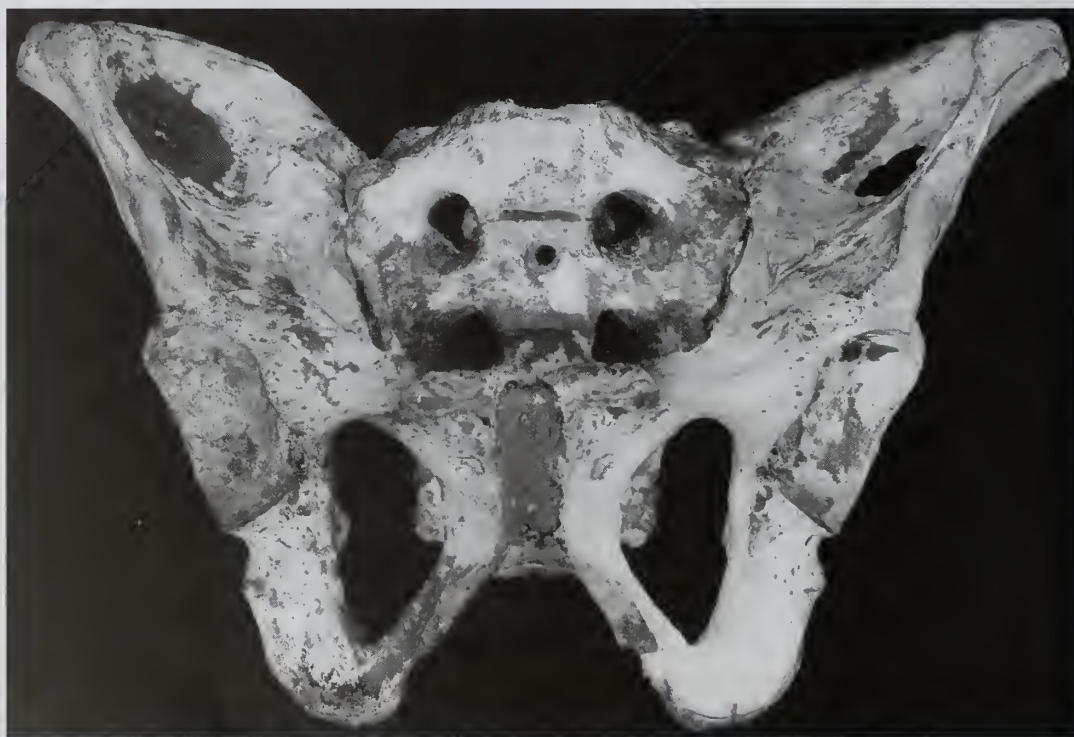


Fig. 5 Ventral view of the articulated Gough's Cave 1 pelvis; $\times 0.6$.

FEMORA

Inventory

Right (No. 1.1/35)

The right femur is essentially complete. There is minor damage to the anterior head margin over an area 15.3mm proximo-distal by 17.0mm antero-posterior, and there was abrasion to the medial margin of the medial condyle which obscures the medial articular margin. In addition, there is matrix adhering to the intertrochanteric crest combined with surface bone damage.

Left (No. 1.1/34)

The left femur is a complete bone with trivial edge abrasion to the condyles, and a loss of surface bone to the postero-proximal head over an area 21.5 by 19.0 mm.

Morphology

The Gough's Cave 1 femora are long, slender and relatively straight bones, with moderate muscular markings. This is combined with moderately sized articulations (Figs 6, 7).

The maximum and bicondylar lengths of the two bones differ



Fig. 6 Anterior (left) and posterior (right) views of the Gough's Cave 1 femora; $\times 0.4$.



Fig. 7 Medial (left) and lateral (right) views of the Gough's Cave 1 femora; $\times 0.4$.

slightly, with the right interarticular lengths being ca.6.0mm longer (Table 5). However, all of this difference is contained within the proximal epiphyses, since the bicondylar trochanteric lengths are identical and the left maximum trochanteric length is slightly longer.

Diaphyses (Tables 5, 6, 8; Figs 6, 7)

The diaphyses are straight medio-laterally with the minimum breadth near midshaft. The femora have moderate anterior curvature, as is indicated by subtense/chord indices of 3.1 and 2.9 versus 3.4 ± 0.7 ($N = 16$) for a Mesolithic sample and 3.5 ± 0.6 ($N = 10$) for a Mesolithic male sample. It is produced primarily by an anterior angulation in the

mid-proximal diaphysis with relatively straight more proximal and distal diaphyseal profiles. As a result, the positions of the maximum subtenses are 43.9% and 39.7% of the chords from their proximal ends, values which are only slightly below the means of variable Mesolithic (46.0 ± 9.0 , $N = 15$) and Mesolithic male (47.1 ± 10.4 , $N = 9$) samples.

The diaphyses exhibit clear asymmetry near midshaft with the right side being larger. This is reflected in larger right side midshaft diameters (Table 5). It is more evident in cross-sectional measures (Tables 6, 8), which exhibit a 6.7% asymmetry in cortical area and a 16.9% asymmetry in the polar moment of area [% asymmetry =

Table 5 Length measurements of the Gough's Cave 1 femora and osteometrics of the femoral diaphyses.

	Right	Left
Maximum length (M-1)	443.0	437.5
Bicondylar length (M-2)	439.0	433.0
Trochanteric length (M-3)	423.0	424.5
Bicondylar trochanteric length (M-4)	413.0	413.0
Biomechanical length ¹	415.3	408.0
Midshaft antero-posterior diameter (M-6)	33.7	30.2
Midshaft medio-lateral diameter (M-7)	24.8	23.8
Midshaft circumference (M-8)	92.0	85.5
Subtrochanteric antero-posterior diameter (M-10) ²	28.2	27.6
Subtrochanteric medio-lateral diameter (M-9)	31.5	31.7
Subtrochanteric circumference	94.0	93.0
Anterior curvature chord (M-27)	303.0	295.0
Anterior curvature subtense	9.5	8.5
Anterior curvature subtense position ³	133.0	117.0

¹ Distance parallel to the diaphyseal axis between the intersection of that axis with the proximal neck (just medial of the greater trochanter) and the average of the positions along the diaphyseal axis of the distal condyles (Ruff & Hayes, 1983).

² The subtrochanteric diameters are taken as the maximum medio-lateral dimension (usually close to the antero-medial to postero-lateral plane of anteversion) and the antero-posterior diameter perpendicular to that medio-lateral one.

³ Distance from the proximal end of the chord to the position of the maximum subtense.

Table 6 Cross-sectional second moments of area of the Gough's Cave 1 femoral diaphyses (in mm⁴ and degrees).

	Right	Left
20% AP second moment of area (I_x)	35927.1	29219.4
20% ML second moment of area (I_y)	39249.1	35295.2
20% Maximum second moment of area ($I_{\max}$)	40399.9	36884.4
20% Minimum second moment of area ($I_{\min}$)	34776.2	27630.1
20% Polar moment of area (J)	75176.1	64514.5
20% Angle of $I_{\max}$ (theta)	27°	25°
35% AP second moment of area (I_x)	35539.9	28073.8
35% ML second moment of area (I_y)	20315.4	20642.1
35% Maximum second moment of area ($I_{\max}$)	35629.1	28972.0
35% Minimum second moment of area ($I_{\min}$)	20226.3	19743.9
35% Polar moment of area (J)	55855.4	48715.9
35% Angle of $I_{\max}$ (theta)	94°	108°
50% AP second moment of area (I_x)	39160.3	28671.0
50% ML second moment of area (I_y)	21418.6	21693.3
50% Maximum second moment of area ($I_{\max}$)	40129.3	30867.6
50% Minimum second moment of area ($I_{\min}$)	20449.5	19496.7
50% Polar moment of area (J)	60578.8	50364.3
50% Angle of $I_{\max}$ (theta)	103°	116°
65% AP second moment of area (I_x)	39874.0	29467.0
65% ML second moment of area (I_y)	23495.7	22797.5
65% Maximum second moment of area ($I_{\max}$)	41309.5	31796.8
65% Minimum second moment of area ($I_{\min}$)	22060.2	20467.7
65% Polar moment of area (J)	63369.7	52264.5
65% Angle of $I_{\max}$ (theta)	106°	117°
80% AP second moment of area (I_x)	30878.2	30129.1
80% ML second moment of area (I_y)	31956.3	31368.4
80% Maximum second moment of area ($I_{\max}$)	33380.3	34249.7
80% Minimum second moment of area ($I_{\min}$)	29454.2	27247.8
80% Polar moment of area (J)	62834.5	61497.5
80% Angle of $I_{\max}$ (theta)	37°	40°

((max - min)/max) × 100]. In contrast, in the proximal diaphysis, even though the right side continues to be larger, the level of asymmetry is much less, with cortical area exhibiting 4.8% asymmetry and the polar moment of area providing only a 2.1% contrast.

The lineae asperae are smooth along the entire lengths of the bones, which is possibly the product of the young adult age of the individual. They are along prominent pilasters for most of the middle half to two-

thirds of the diaphysis. The pilasters are formed by antero-posteriorly convex medial surfaces but distinctly antero-posteriorly concave lateral surfaces. This results in a sulcus along the lateral pilaster especially in the midshaft region. The lineae asperae taper off gradually disto-medially, ending in moderate adductor tubercles.

The prominence of the Gough's Cave 1 pilasters is evident by their pilastic indices of 135.9 and 126.9. Both of them, and especially the right one, are well above the means of Mesolithic (109.5 ± 10.6, N = 52) and Mesolithic male (113.0 ± 9.2, N = 34) samples. This is further and better illustrated, albeit with smaller comparative samples, by the Gough's Cave 1 I_x/I_y and $I_{\max}/I_{\min}$ ratios (Table 7) along the middle third of the diaphysis (the 35%, 50% and 65% sections). Again, the right femur is more pilastic than the left one.

Proximally, the markings in the pectineal region are very light, and they are bordered laterally by small but rugose gluteal tuberosities (Fig. 8). Neither gluteal tuberosity is projecting or concave, and there is no trace of hypotrochanteric fossae. The right tuberosity fades out proximally, but the left one leads to a small tubercle at the proximo-distal level of the lesser trochanter. The modest dimensions of the Gough's Cave 1 gluteal tuberosities are demonstrated by comparisons of their maximum breadths. The absolute breadths (8.2 and 8.4 mm) are below the means Mesolithic (11.6 ± 1.9 mm, N = 17) and especially Mesolithic male (12.3 ± 1.9 mm, N = 10) samples. This is further illustrated by indices between the gluteal tuberosity breadths and the geometric means of the associated subtrochanteric diaphyseal diameters – the mean of the resultant values of 27.5 and 28.4 for Gough's Cave 1 are 1.91 and 1.98 standard deviations below the means respectively of Mesolithic (42.3 ± 7.5, N = 17) and Mesolithic male (43.0 ± 7.6, N = 10) samples.

The gluteal buttresses are pronounced, with distinct sulci formed anteriorly and posteriorly. The right one is covered posteriorly by the gluteal tuberosity, but the left gluteal tuberosity covers only the medial half of the buttress. Nonetheless, the subtrochanteric diaphyses of Gough's Cave 1 are relatively round compared to those of most Mesolithic femora. Its meric indices of 89.5 and 87.1 are 2.49 and 2.84 standard deviations above the means respectively of pooled Mesolithic (74.6 ± 5.5, N = 85) and Mesolithic male (75.8 ± 4.4, N = 50) samples. However, the large sample Muge has significantly lower meric indices (73.0 ± 4.8, N = 55) than the remainder of the Mesolithic sample (P < 0.001). Yet even using only non-Muge Mesolithic remains for the comparison still places the Gough's Cave 1 femora 1.93 standard deviations from the mean (77.5 ± 5.6, N = 30). Similarly, the proximal diaphyseal (80%) $I_{\max}/I_{\min}$ ratios are 2.43 and 2.70 standard deviations below the means of respective Mesolithic samples (Table 7).

Table 7 Comparative femoral second moment of area diaphyseal shape indices, I_x/I_y and $I_{\max}/I_{\min}$, for Gough's Cave 1 and Mesolithic samples. For Mesolithic samples, mean ± SD is given.

I_x/I_y	Gough's Cave 1: Right; Left	Mesolithic Sample	Mesolithic Males
20%	0.92; 0.83	0.66 ± 0.08; N = 16	0.68 ± 0.07; N = 10
35%	1.75; 1.36	1.01 ± 0.15; N = 14	1.02 ± 0.20; N = 8
50%	1.83; 1.32	1.18 ± 0.23; N = 55	1.20 ± 0.22; N = 37
65%	1.70; 1.29	1.00 ± 0.21; N = 15	1.08 ± 0.17; N = 9
80%	0.97; 0.96	0.77 ± 0.20; N = 52	0.79 ± 0.19; N = 34
$I_{\max}/I_{\min}$			
20%	1.16; 1.33	1.58 ± 0.19; N = 13	1.54 ± 0.18; N = 8
35%	1.76; 1.47	1.20 ± 0.12; N = 11	1.26 ± 0.12; N = 6
50%	1.96; 1.58	1.33 ± 0.19; N = 45	1.33 ± 0.19; N = 30
65%	1.87; 1.55	1.32 ± 0.26; N = 12	1.25 ± 0.13; N = 7
80%	1.13; 1.26	1.90 ± 0.29; N = 41	1.87 ± 0.25; N = 27

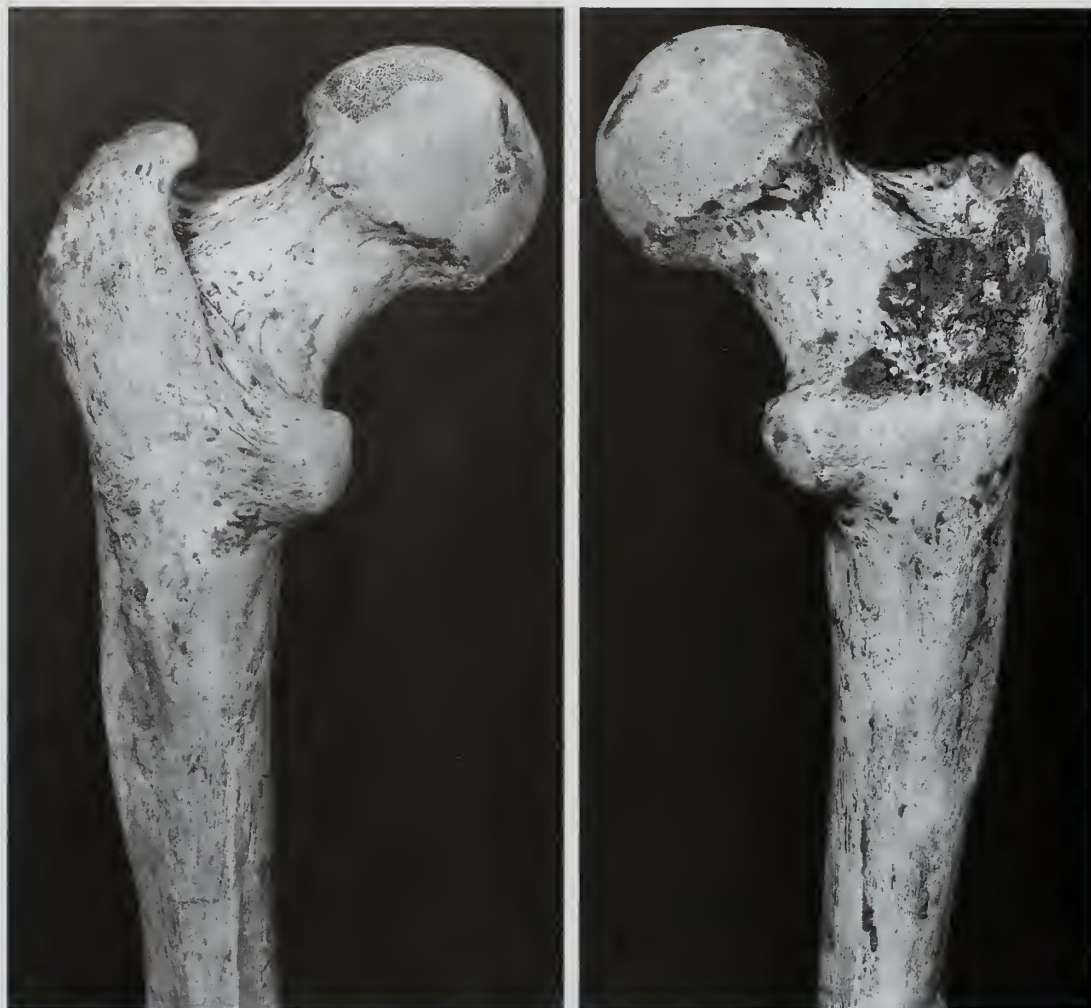


Fig. 8 Proximo-posterior view of the Gough's Cave 1 femora: $\times 0.8$ (enlargement of Fig. 6, top right).

Table 8 Cross-sectional area measures of the Gough's Cave 1 femoral diaphyses (in mm²).

	Right	Left
20% Total area (TA)	806.3	751.3
20% Cortical area (CA)	390.4	343.3
20% Medullary area (MA)	415.9	408.0
35% Total area (TA)	612.0	562.8
35% Cortical area (CA)	390.4	417.9
35% Medullary area (MA)	221.6	144.9
50% Total area (TA)	595.3	552.9
50% Cortical area (CA)	507.2	473.3
50% Medullary area (MA)	88.1	79.6
65% Total area (TA)	618.8	572.5
65% Cortical area (CA)	544.1	479.5
65% Medullary area (MA)	74.7	93.0
80% Total area (TA)	668.0	668.8
80% Cortical area (CA)	433.4	412.7
80% Medullary area (MA)	234.6	256.1

The overall robusticity of the femoral diaphyses can be compared to those of relatively large samples of European Mesolithic femora using its midshaft external diameters [$((AP \times ML)^{1/2} / \text{bicondylar length}) \times 100$]. The resultant indices are 6.6 and 6.2 for Gough's

Table 9 Comparative femoral percent cortical area (%CA = (CA/TA) $\times$ 100) for Gough's Cave 1 and Mesolithic samples.

	Gough's Cave 1: Right; Left	Mesolithic Sample	Mesolithic Males
20%	48.4; 45.6	48.2 ± 4.1 ; N = 16	47.3 ± 3.6 ; N = 10
35%	63.8; 74.3	67.3 ± 5.8 ; N = 14	65.1 ± 3.3 ; N = 8
50%	85.2; 85.6	79.0 ± 6.9 ; N = 55	77.9 ± 6.3 ; N = 37
65%	87.9; 83.6	86.3 ± 2.6 ; N = 15	85.7 ± 2.7 ; N = 9
80%	64.9; 61.7	77.6 ± 8.3 ; N = 52	78.1 ± 6.8 ; N = 34

Cave 1, the right one of which is on the means of Mesolithic (6.5 ± 0.4 , N = 47) and Mesolithic male (6.6 ± 0.4 , N = 31) samples and the left one only slightly below them. In this, the large Muge sample has a significantly ($P = 0.002$) lower mean (6.3 ± 0.2 , N = 19), but its inclusion or deletion from the Mesolithic sample has little effect on the relative position of Gough's Cave 1.

Using midshaft cross-sectional measures, the percent cortical areas largely cluster close to the Mesolithic comparative means; only the 80% one is relatively low, significantly so with respect to the Mesolithic male sample (Table 9). Plots of the midshaft cortical area and polar moment of area versus powers of femoral length (Fig. 9) largely support the pattern seen in the robusticity indices; Gough's

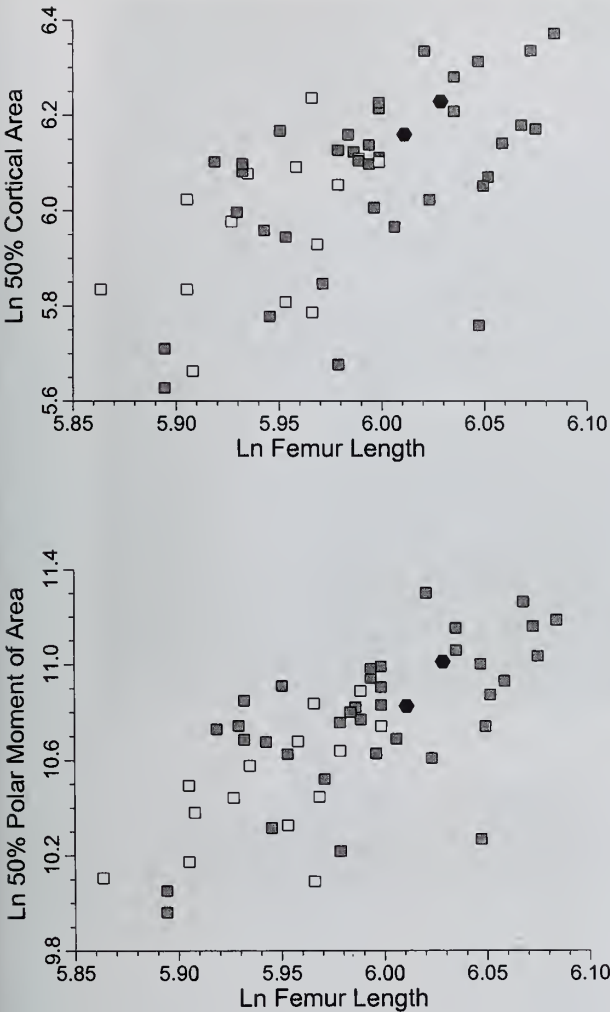


Fig. 9 Plots of the Gough's Cave 1 femoral midshaft logged cross-sectional parameters vs. ln length (see text). Solid hexagons: Gough's Cave 1 right and left femora; gray squares: Mesolithic males; open squares: Mesolithic females.

Cave 1 is well within the Mesolithic distributions, close to the middles of the comparative sample distributions in both measures.

Proximal Epiphyses (Table 10; Fig. 10)

The proximal epiphyses present overall similar morphologies but contrast in several aspects of their proportions, some of which are reflected in the slight (ca.1%) length asymmetry. The heads are evenly rounded and each has a large fovea capitis placed slightly posterior on the head. There is no trace of an Allen's fossa on either femur. The right head is slightly larger, especially in the cranio-caudal direction (Table 10), but comparisons of their head sagittal diameters to femoral bicondylar length produce similar indices (10.9 & 10.7), in part due to the differences in femoral lengths. They are both very close to the means of Mesolithic (10.7 ± 0.5, N = 37) and Mesolithic male (10.8 ± 0.5, N = 26) samples.

On the left femur where it is preserved, there is a large obturator fossa with a large pit 12.5mm deep from its posterior edge. The intertrochanteric crest has clearly marked fibrous spicules running

Table 10 Osteometrics of the Gough's Cave 1 femoral epiphyses.

	Right	Left
Head-neck length (M-14)	80.1	79.9
Anatomical biomechanical neck length ¹	37.0	40.0
Trochanteric biomechanical neck length ²	63.0	67.0
Head sagittal diameter (M-19)	47.7	46.3
Head vertical diameter (M-18)	48.2	46.3
Neck circumference (M-17)	97.0	91.5
Neck-shaft angle (M-29) ³	132°	135°
Anteversion angle (M-28)	11°	30°
Greater trochanter depth (M-26(1))	–	37.3
Gluteal tuberosity breadth ⁴	8.2	8.4
Distal epicondylar breadth (M-21)	–	78.5
Bicondylar breadth ⁵	(75.6)	76.6
Medial condylar breadth (M-21c)	(29.4)	29.6
Lateral condylar breadth (M-21e)	28.3	28.6
Bicondylar angle (M-30)	10°	10°
Medial patellar projection (M-24b)	60.7	58.9
Lateral patellar projection (M-22)	63.6	61.9
Median patellar projection ⁶	59.0	58.9
Patellar surface circumference ⁷	42.0	45.0
Patellar surface breadth (M-26(3b))	37.7	39.1
Patellar surface depth ⁸	6.0	6.5
Patellar surface depth position ⁹	13.6	13.6

¹ Distance perpendicular to the diaphyseal axis from that axis to the proximal tangent to the femoral head.
² Distance perpendicular to the diaphyseal axis from the proximo-distal tangent to the lateral greater trochanter to the proximal tangent to the femoral head (Lovejoy *et al.*, 1973).
³ Taken in the anteversion plane of the femoral head and neck.
⁴ Maximum breadth of the rugose area for the insertion of *M. gluteus maximus* on the proximal diaphysis (Trinkaus, 1976).
⁵ Maximum breadth across the external medial and lateral condylar surfaces.
⁶ Dorsal condylar plane to the tangent parallel to that dorsal plane within the deepest portion of the patellar sulcus.
⁷ Articular arc in the patellar sulcus from the intercondylar margin to the proximal patellar surface.
⁸ Maximum depth subtense to the sulcus floor, taken from the surface breadth.
⁹ Position of the depth subtense from the lateral margin of the patellar surface.

along it, from the capsular attachment, but the intertrochanteric lines on the anterior surfaces are faint. Both lesser trochanters are strongly medially projecting, and the greater trochanters have a clear lateral swelling below the *M. gluteus medius* insertion. The left greater trochanter also exhibits a strong beak at its proximo-medio-posterior margin.

The neck shaft angles of the two femora show a moderate degree of asymmetry, with the left one being 3° higher. Both of these angles (132° & 135°) are relatively high for foraging populations (Trinkaus, 1993) but not exceptional for a European Mesolithic sample (125.5° ± 5.9°, N = 22) or a male one (124.4° ± 5.4°, N = 15). However, the Gough's Cave 1 values nonetheless have z-scores of 1.36 and 1.68 respectively.

Of greater asymmetry are the anteversion angles, a modest 11° on the right side but a pronounced 30° on the left. This asymmetry in anteversion angles is reflected in direction but not in degree by the values for theta at the subtrochanteric level (37° and 40° respectively). In comparison, a variable Mesolithic sample provides anteversion angle values of 18.2° ± 9.0° (N = 18) and 18.3° ± 8.7° (N = 12) for males alone.

The relatively high neck-shaft angles of Gough's Cave 1 contribute in part to its relatively short biomechanical neck lengths, which provide indices relative to bicondylar length 8.4 and 9.2 for the anatomical biomechanical neck length and 14.4 and 15.5 for the trochanteric one. These are relative respectively to 9.6 ± 0.9 (N = 11) and 16.7 ± 1.0 (N = 10) for the Mesolithic sample and 9.5 ± 0.8 (N = 7) and 16.9 ± 0.7 (N = 6) for the male sample.

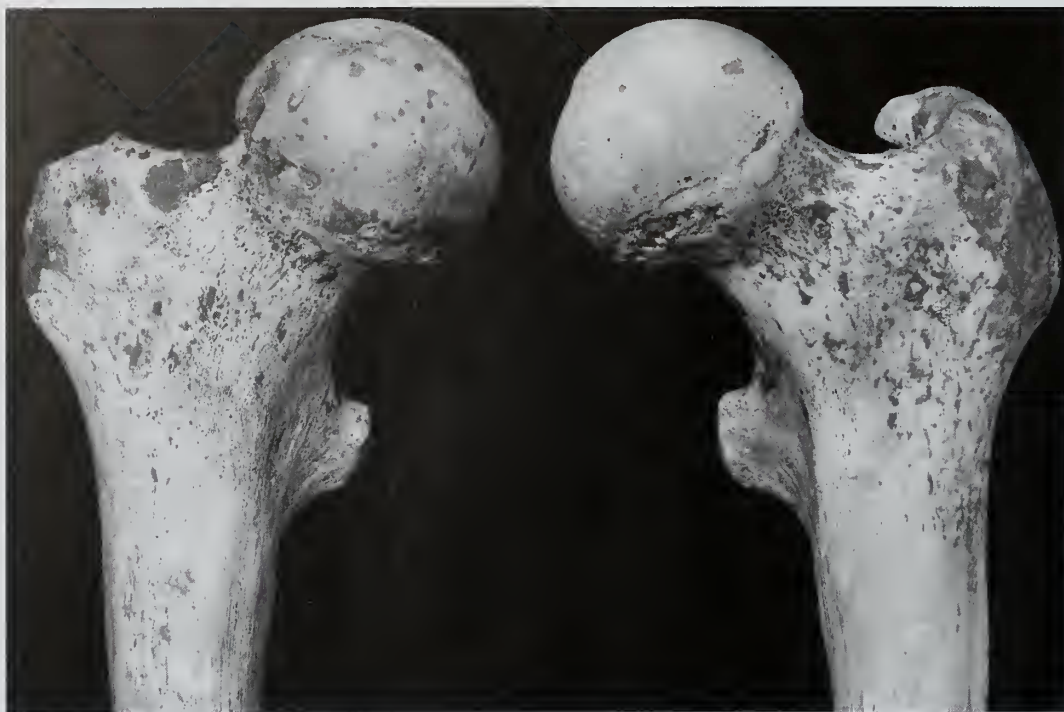


Fig. 10 Anterior view of the Gough's Cave 1 proximal femora; $\times 0.8$ (enlargement of Fig. 6, top left).

Distal Epiphyses (Table 10)

There is little of note on the Gough's Cave 1 distal femoral epiphysis. The condyles are rounded with no evidence of femoral squatting facets. There is only a small rounded ridge along the supracondylar margin of the medial condyles, up to 3.5mm from the condylar surface on the left side where it is best preserved.

Their bicondylar angles of 10° each are well within Mesolithic ranges of variation ($9.7^\circ \pm 3.1$, $N = 19$; $8.8^\circ \pm 2.5^\circ$, $N = 15$ for males only), all of which are similar to those of recent humans (Tardieu & Trinkaus, 1994). The one measure of distal epiphyseal size for which reasonable Mesolithic comparative samples exist, epicondylar breadth versus bicondylar length, provides an index of 18.1. It suggests a modest but not unusually small epiphysis, given means of 18.8 for total (± 1.1 , $N = 19$) and 18.9 for male (± 1.1 , $N = 14$) Mesolithic samples.

TIBIAE

Inventory

Right (No. 1.1/27)

A complete bone with minor abrasion to the medial half of the posterior distal epiphysis and thin adhering matrix around the proximal epiphysis.

Left (No. 1.1/26)

The bone retains two pieces, a proximal posterior piece of the diaphysis with the abraded soleal line (maximum preserved length: ca.80.0mm) and a diaphyseal section with all of the surfaces just proximal of the distal epiphysis (maximum preserved length: ca.50.0mm). Both of the pieces are set in a plaster and papier-mâché reconstruction of the bone and attached to the left fibula (Fig. 11).

Morphology

Even though portions of both tibiae are present, meaningful morphological observations can be made primarily on the essentially complete right bone. Therefore, the following comments apply to the right bone except where noted otherwise.

Diaphysis (Tables 11, 12, 14; Figs 11, 12)

The right tibial diaphysis has a gently 'S'-curved, sharply angled anterior crest, which is bordered medially by a smooth and slightly convex medial diaphyseal surface. The lateral surface is convex between the interosseus crest and the anterior margin and concave between the crest and the postero-lateral corner along the proximal two-thirds of the diaphysis. Distal of there, it becomes fully convex. The postero-medial margin is rounded proximal of the meeting of the soleal line with that margin, near midshaft.

Both tibiae have a distinct but small flexor line, a crest between the origins of *M. tibialis posterior* and *M. flexor digitorum longus* on the proximal posterior diaphysis extending distally from the soleal line. On the right bone, it is raised from the subperiosteal surface along ca.78mm distally from the soleal line. The soleal line itself is a low rugose area proximal of the flexor line, 4.7mm wide near the flexor line and 5.3mm wide more proximally. Disto-medial of the flexor line, the soleal line becomes a slightly raised crest, extending to the medial side distally. The interosseus line is a distinct crest from the very proximal shaft to about midshaft, at which level it becomes blunt and blends in with the lateral diaphysis.

The nutrient foramen is located just medial of the flexor line, 37.5mm distal of the intersection of the two muscular lines.

The Gough's Cave 1 tibial diaphysis, like those of other Mesolithic humans, is distinctly platynemic. Its cnemic index of 55.9 is even slightly below the means of Mesolithic (62.4 ± 5.8 , $N = 73$) and Mesolithic male (61.8 ± 6.2 , $N = 46$) samples. Moreover, its 35% to 80% $I_{\max}/I_{\min}$ ratios are all higher than the means of Mesolithic

Table 11 Osteometrics of the Gough's Cave 1 right tibia.

Maximum length (M-1)	385.0
Medial total length (M-1b)	375.0
Medial articular length (M-2)	360.0
Biomechanical length ¹	360.5
Midshaft antero-posterior diameter (M-8)	34.3
Midshaft medio-lateral diameter (M-9)	21.3
Midshaft circumference (M-10)	87.5
Proximal antero-posterior diameter (M-8a)	38.1
Proximal medio-lateral diameter (M-9a)	21.3
Proximal circumference (M-10a)	94.0
Distal minimum circumference (M-10b)	77.0
Proximal epiphyseal maximum breadth (M-3)	76.1
Medial condyle breadth (M-3a)	34.5
Lateral condyle breadth (M-3b)	34.4
Medial condyle depth (M-4a)	46.7
Lateral condyle depth (M-4b)	40.9
Tuberosity projection ²	48.0
Medial retroversion angle (M-12)	16°
Lateral retroversion angle	13°
Medial inclination angle (M-13)	11°
Lateral inclination angle	8°
Torsion angle (M-14)	20°
Distal maximum breadth (M-6)	49.1
Distal maximum depth (M-7)	40.3
Talar trochlear articular breadth ³	30.0
Medial talar articular depth ⁴	26.2
Lateral talar articular depth ⁵	33.7

¹ The average distance, measured parallel to the diaphyseal axis, from the middle of the talar trochlear surface to the middle of each condyle (Ruff & Hayes, 1983).
² The distance perpendicular to the diaphyseal axis from the antero-posterior middle of the condyles to the coronal plane tangent to the anterior surface of the tibial tuberosity (Trinkaus, 1983).
³ The medio-lateral breadth of the talar trochlear facet from the antero-posterior middle of the lateral margin to the middle of the curve between the trochlear and the medial malleolar facets (Trinkaus, 1983; Ruff, 1990).
⁴ The minimum antero-posterior dimension of the talar trochlear facet taken adjacent to the medial malleolus (Trinkaus, 1983; Ruff, 1990).
⁵ The maximum antero-posterior dimension of the talar trochlear facet taken adjacent to the fibular articulation (Trinkaus, 1983; Ruff, 1990).

Table 12 Second moments of area of the Gough's Cave 1 right tibial diaphysis (in mm⁴ and degrees).

20% AP second moment of area (I _x)	14154.4
20% ML second moment of area (I _y)	12798.3
20% Maximum second moment of area (I _{max})	15461.6
20% Minimum second moment of area (I _{min})	11491.1
20% Polar moment of area (J)	26952.7
20% Angle of I _{max} (theta)	125°
35% AP second moment of area (I _x)	17618.5
35% ML second moment of area (I _y)	12738.0
35% Maximum second moment of area (I _{max})	21220.1
35% Minimum second moment of area (I _{min})	9136.4
35% Polar moment of area (J)	30356.5
35% Angle of I _{max} (theta)	119°
50% AP second moment of area (I _x)	29204.5
50% ML second moment of area (I _y)	15067.5
50% Maximum second moment of area (I _{max})	33212.7
50% Minimum second moment of area (I _{min})	11059.3
50% Polar moment of area (J)	44272.0
50% Angle of I _{max} (theta)	113°
65% AP second moment of area (I _x)	42160.0
65% ML second moment of area (I _y)	16796.3
65% Maximum second moment of area (I _{max})	46262.6
65% Minimum second moment of area (I _{min})	12693.7
65% Polar moment of area (J)	58956.3
65% Angle of I _{max} (theta)	111°
80% AP second moment of area (I _x)	58126.5
80% ML second moment of area (I _y)	32073.3
80% Maximum second moment of area (I _{max})	65287.7
80% Minimum second moment of area (I _{min})	24912.2
80% Polar moment of area (J)	90199.9
80% Angle of I _{max} (theta)	115°

Table 13 Comparative tibial second moment of area diaphyseal shape indices, I_{max}/I_{min}, for Gough's Cave 1 and Mesolithic samples.

	Gough's Cave 1	Mesolithic Sample	Mesolithic Males
20%	1.35	1.38 ± 0.25; N = 12	1.32 ± 0.22; N = 7
35%	2.32	2.23 ± 0.40; N = 13	2.19 ± 0.34; N = 8
50%	3.00	2.59 ± 0.46; N = 47	2.63 ± 0.47; N = 34
65%	3.64	2.89 ± 0.44; N = 16	2.86 ± 0.41; N = 10
80%	2.62	2.44 ± 0.46; N = 11	2.47 ± 0.53; N = 8

Table 14 Cross-sectional areas of the Gough's Cave 1 right tibial diaphysis (in mm²).

20% Total area (TA)	480.2
20% Cortical area (CA)	224.1
20% Medullary area (MA)	256.1
35% Total area (TA)	432.5
35% Cortical area (CA)	299.5
35% Medullary area (MA)	133.0
50% Total area (TA)	491.1
50% Cortical area (CA)	375.8
50% Medullary area (MA)	115.3
65% Total area (TA)	566.8
65% Cortical area (CA)	404.4
65% Medullary area (MA)	162.4
80% Total area (TA)	793.7
80% Cortical area (CA)	432.5
80% Medullary area (MA)	361.2

Table 15 Comparative tibial percent cortical area (%CA = (CA/TA) × 100) for Gough's Cave 1 and Mesolithic samples.

	Gough's Cave 1	Mesolithic Sample	Mesolithic Males
20%	46.7	57.3 ± 4.8; N = 15	55.8 ± 3.9; N = 9
35%	69.2	81.0 ± 3.0; N = 16	80.8 ± 2.5; N = 10
50%	76.5	84.4 ± 5.0; N = 53	85.0 ± 4.4; N = 38
65%	71.4	68.6 ± 4.5; N = 16	68.2 ± 4.3; N = 10
80%	54.5	51.2 ± 5.0; N = 15	51.3 ± 5.4; N = 8

samples, with the 50% and especially the 65% ratios being well above those Mesolithic means (Table 13).

In terms of diaphyseal robusticity, the Gough's Cave 1 tibia on average is similar to those of other Mesolithic specimens. Its percent cortical area values are below Mesolithic means for the mid and distal diaphysis, but above those means in the proximal diaphysis (Table 15). A diaphyseal robusticity index (from the geometric mean of the midshaft diameters versus articular length) is 7.5 for Gough's Cave 1, which is very close to the means of Mesolithic (7.6 ± 0.6, N = 24) and Mesolithic male (7.8 ± 0.6, N = 17) samples. The plots of midshaft cortical area and polar moment of area versus appropriate powers of femoral or tibial and femoral length (Fig. 13) place Gough's Cave 1 clearly well within the Mesolithic ranges of variation is slightly below a number of those specimens.

Proximal Epiphysis (Fig. 14)

The tibial plateau presents small intercondylar spines, a distinctly concave medial condylar surface, and an evenly convex lateral condylar surface. There is a nearly horizontal fibular facet, with its maximum dimension of 20.2mm approximately medio-lateral and the minimum diameter of 14.5mm approximately antero-posterior. There is a clear sulcus for the *M. semimembranosus* tendon, but there is no smoothing of the bone in the sulcus for its insertion.

The tibial plateau is strongly rotated relative to the diaphysis, with a torsion angle of 20°. However, this value is close to the means of variable Mesolithic (22.7° ± 12.4°, N = 15) and Mesolithic male

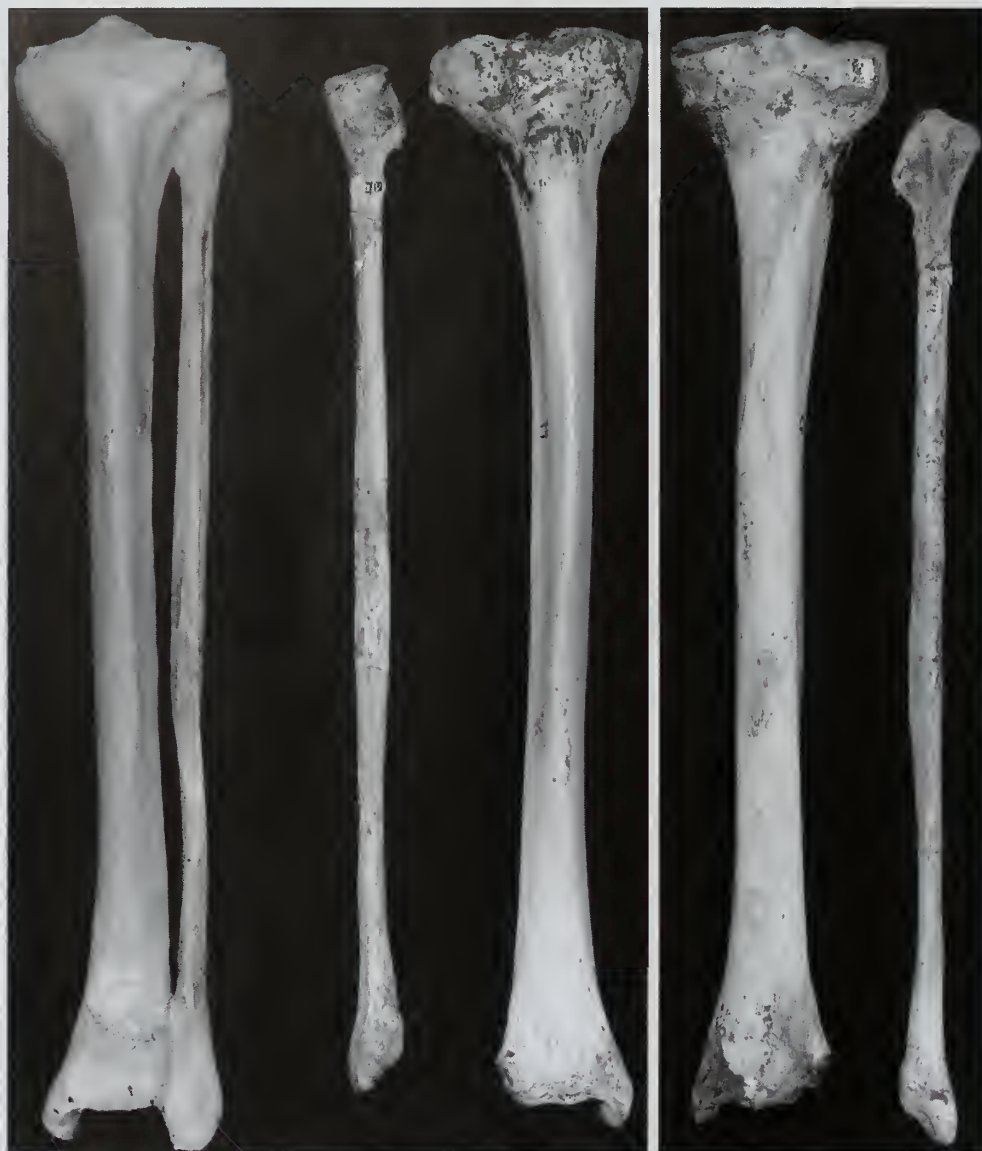


Fig. 11 Anterior (left) and posterior (right) views of the Gough's Cave 1 tibiae and fibulae, with the heavily reconstructed left tibia and fibula shown only in anterior view; $\times 0.4$.

($22.4^\circ \pm 9.9$, $N = 12$) samples. The Gough's Cave 1 tibia also has clear retroversion of the condyles, with a medial retroversion angle of 15° . However, this value is also very close to the means of Mesolithic ($15.3 \pm 5.1^\circ$, $N = 18$) and Mesolithic male ($15.0^\circ \pm 4.7^\circ$, $N = 15$) samples. All of these retroversion angles are normal for non-industrial recent humans (Trinkaus, 1975a).

Similarly, the overall dimensions of the tibial plateau, quantified by an index of maximum breadth versus articular length of 21.1 for Gough's Cave 1, is normal for Mesolithic samples (22.4 ± 1.8 , $N = 12$, and 22.1 ± 1.5 , $N = 11$ for males only). One feature in which the Gough's Cave 1 proximal tibia is further from the mean of the comparative samples is in relative tuberosity projection, or the posterior displacement of the tibial condyles from the tibial tuberosity (a measure of the *M. quadriceps femoris* moment arm through the patellar ligament). The Gough's Cave 1 value of 13.3 is significantly

above the mean of a small Mesolithic pooled-sex sample (9.4 ± 1.4 , $N = 6$), and still well above the mean of a male sample (10.5 ± 2.0 , $N = 4$).

Distal Epiphysis

The Gough's Cave 1 tibial distal epiphysis is likewise unremarkable. Its talar trochlear articular surface, relative to tibial length, is similar in size to other Mesolithic tibiae. The index formed by the geometric mean of its breadth with the average of its depth measurements versus articular length is 8.3 – this value is close to the means for Mesolithic (8.1 ± 0.6 , $N = 23$) and Mesolithic male (8.1 ± 0.6 , $N = 18$) samples.

It does present a clear lateral squatting facet, 9.0mm wide and 3.7mm proximo-distal. There is no trace of a medial squatting facet or other rounding of the anterior articular margin.



Fig. 12 Medial (left) and lateral (right) views of the Gough's Cave 1 right tibia and fibula; $\times 0.4$.

FIBULAE

Inventory

Right (No. 1.1/28)

The bone consists of a proximal section with the proximal epiphysis and the proximal half of the diaphysis, plus a distal section with the distal quarter of the diaphysis and the complete distal epiphysis. The two pieces are joined together by a plaster reconstruction of the mid-distal epiphysis (minimum gap: 47.8mm), and its reconstructed lengths (Table 16) are based on articulation with the complete right tibia.

Left (No. 1.1/26)

Most of the diaphysis lacking both epiphyses. The epiphyses are reconstructed in plaster and joined to the reconstructed left tibia. Maximum preserved length: 279.0mm.

Morphology

Even though both of the diaphyses are preserved, most of the morphological information and all of the osteometrics derive from the separated right fibula. Nonetheless, osteometric comparisons of the Gough's Cave 1 fibula are limited by poor preservation and limited published measurements for other European Mesolithic fibulae.

Diaphyses (Table 16; Figs 11, 12)

Both fibular diaphyses are very straight, with well formed angles for musculo-ligamentous attachments on all of the margins. On anterior view, the left one has a slight 'S' curve in the distal third, producing a slight lateral concavity just below midshaft – the right bone's reconstruction in this region (Fig. 11) may therefore be too straight.

Even though the various angles are clearly formed, none of them present clear rugosities. The primary evident muscular insertions

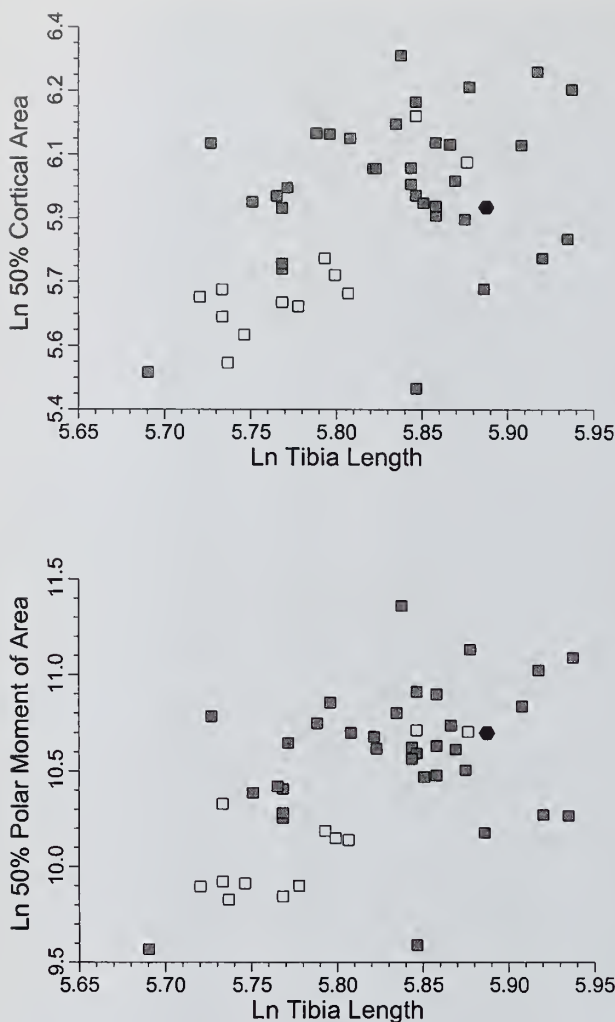


Fig. 13 Plots of the Gough's Cave 1 tibial midshaft logged cross-sectional parameters versus loggen tibial length. Solid hexagons: Gough's Cave 1 right and left femora; gray squares: Mesolithic males; open squares: Mesolithic females.

areas are the soleal line proximally (preserved on the right bone) and a broad area on the posterior midshaft (evident on both fibulae). The soleal line is a broad, rugose area, 13.5mm long and up to 12.7mm wide. It forms a slight depression and has a small lip medially. The right midshaft exhibits a broad rugose area ca.40.0mm long along the posterior surface. A similar but much less rugose area is present on the left diaphysis. The attachments for the distal interosseus (or tibio-fibular) ligaments are modest, spiraling from proximo-anterior to disto-posterior.

Morphometrically, the Gough's Cave 1 right fibula is similar to those of other Mesolithic humans. Its midshaft maximum to minimum diameter index of 133.6 is moderately below to the means of highly variable samples (Mesolithic: 141.6 ± 17.7 , $N = 40$; Mesolithic males: 140.0 ± 18.6 , $N = 22$). It is slightly less robust than most other Mesolithic fibulae, as indicated by an index between the geometric mean of its midshaft diameters and maximum length (Gough's Cave 1: 3.8; Mesolithic: 4.2 ± 0.6 , $N = 20$; Mesolithic males: 4.2 ± 0.3 , $N = 13$).

It is also possible, with smaller comparative samples, to assess its

Table 16 Osteometrics of the Gough's Cave 1 right fibula.

Maximum length (M-1)	(366.0)
Articular length (M-1a)	(356.0)
Midshaft maximum diameter (M-2)	15.9
Midshaft minimum diameter (M-3)	11.9
Midshaft circumference (M-4)	45.5
Neck maximum diameter	13.1
Neck minimum diameter	10.5
Neck circumference (M-4a)	37.0
Proximal epiphyseal medio-lateral diameter	29.8
Proximal epiphyseal antero-posterior diameter	24.4
Proximal tibial facet medio-lateral diameter	20.9
Proximal tibial facet antero-posterior diameter	18.2
Proximal articular angle ¹	111°
Distal maximum depth ²	24.9
Distal articular depth ³	19.5
Distal articular length ⁴	22.7
Distal articular angle ⁵	19°

¹ The angle between the antero-medial to postero-lateral plane of the proximal tibial facet and the diaphyseal axis.

² The maximum antero-posterior diameter of the epiphysis, measured parallel to the talar surface.

³ The maximum antero-posterior diameter of the talar articular surface.

⁴ The maximum proximo-distal diameter of the talar articular facet, measured parallel to the long axis of the facet.

⁵ The angle in coronal plane of the talocrural articulation between the chord for the articular height and the diaphyseal axis.

neck proportions. A maximum to minimum diameter index of 124.8 for Gough's Cave 1 is relatively low (Mesolithic: 141.9 ± 13.2 , $N = 4$). However, the size of its neck circumference vis-à-vis midshaft circumference (81.3) is close to the values for other Mesolithic fibulae (79.8 ± 2.2 , $N = 4$).

Proximal Epiphysis

The right fibula preserves a large rounded head with a subcircular flat facet for the tibia. It is notable primarily for its development of a very large ossification of the proximal tibio-fibular ligament (Fig. 11). The crest is rounded on its medial margin, 22.8mm long (proximo-distally), 13.1mm thick, and projects ca.9.0mm from the adjacent head. Interestingly, there is no counterpart on the proximal tibia, only the tapering off of the modest interosseus line previously noted.

Distal Epiphysis

The right distal epiphysis generally smooth in its external surfaces. The digital fossa is modest in size, and the malleolar surface is gently convex in a proximo-distal direction. The angle between the proximo-distal chord of the articular surface relative to the diaphyseal axis (19°) falls close to means of variable Mesolithic ($20.1^\circ \pm 6.5^\circ$, $N = 7$) and Mesolithic male ($21.0^\circ \pm 6.4^\circ$, $N = 5$) samples.

TALUS

Inventory

Right (No. 1.1/29)

A complete bone, which has had holes drilled in the medial calcaneal surface and the sulcus tali for analytical samples.

Morphology

The right talus of Gough's Cave 1 (Table 17; Fig. 15) is a modest bone with generally smooth surfaces. In overall length relative to femoral length, it is very close to other Mesolithic specimens [12.6 versus 12.6 ± 0.4 for Mesolithic ($N = 11$) and male Mesolithic ($N = 6$) samples]. Similarly, its relative trochlear length (versus length)



Fig. 14 Views of the Gough's Cave 1 right tibial epiphyses. Left: posterior proximal epiphysis and diaphysis. Above right: proximal medial epiphysis. Below right: anterior distal epiphysis; $\times 0.8$ (enlargement of parts of Figs 11, 12).

index of 65.1 is just below the means of variable Mesolithic (65.4 ± 4.1 , $N = 10$) and male Mesolithic (65.3 ± 4.2 , $N = 6$) samples. However, its trochlea is slightly narrower than those of most Mesolithic tali, since a trochlear breadth/length index provides a value of 79.1 for Gough's Cave 1, but means of $84.5 (\pm 7.5, N = 26)$ and $82.8 (\pm 6.3, N = 18)$ for pooled-sex and male only Mesolithic samples. Finally, its neck shaft angle of 23° falls in the middles of the ranges of Mesolithic ($24.1^\circ \pm 4.4^\circ$, $N = 7$) and male Mesolithic ($22.9^\circ \pm 3.5^\circ$, $N = 6$) samples.

On its talo-crural articulations, it presents several variants of the anterior trochlear margin (Table 18). There is a full anterior extension of the medial malleolar surface with an associated medial extension of the trochlear margin. The lateral trochlear margin likewise extends anteriorly, and abuts against a lateral squatting facet, the latter matching the one on the distal tibia.

Plantarily, the medial and anterior calcaneal facets are partially fused. They exhibit a non-articular wedge extending 7.8mm in from the sulcus tali, leading up to a clear fusion line 8.4mm long. In addition, the posterior 8.4mm of the margin between the anterior calcaneal facet and the talar head along the postero-medial portion of their border is open.

The bone lacks a clear sulcus tali facet on the anterior margin of

the posterior calcaneal surface, but it presents rounding of that surface along its more anterior sulcus tali margin. In addition, there is a swelling of non-articular bone 14.7mm long in the antero-medial portion of the postero-medial end of the sulcus tali. It is up to 4.4mm wide, and it abuts against the posterior margin of the medial calcaneal facet, remaining separate from the posterior facet.

Finally, the posterior calcaneal facet has a persistent small sulcus 3.0mm long extending in near the posterior end of the postero-lateral margin of the facet. It is the result of incomplete fusion of the ossification center for the lateral posterior tubercle to the talus.

CUBOID

Inventory

Right (No. 1.1/30).
Complete undamaged bone.

Morphology

The right cuboid bone of Gough's Cave 1 (Table 19; Fig. 15) is a



Fig. 15 Dorsal (above) and plantar (below) views of the Gough's Cave 1 right talus and cuboid bone; $\times 0.9$.

Table 17 Osteometrics of the Gough's Cave 1 right talus.

Maximum (lateral) length ¹	60.5
Length (M-1)	55.0
Articular height (M-3b)	26.0
Articular breadth (M-2b)	46.7
Trochlear length (M-4)	35.8
Trochlear breadth (M-5)	28.3
Trochlear height (M-6)	11.4
Lateral malleolar height ²	26.5
Lateral malleolar oblique height (M-7a)	28.0
Lateral malleolar breadth (M-7)	9.0
Lateral malleolar length ³	29.5
Head and neck length (M-8)	20.0
Head length (M-9)	37.2
Head breadth (M-10)	21.6
Posterior calcaneal length (M-12)	35.0
Posterior calcaneal breadth (M-13)	23.5
Trochlear angle ⁴	5°
Neck angle (M-16)	23°
Torsion angle (M-17)	34°
Posterior calcaneal angle (M-15)	41°
Subtalar angle ⁵	59°

¹ Distance from the distal head to the proximal lateral tubercle parallel to the sagittal plane of the trochlea.

² Distance from plantar-lateral tip of the lateral malleolar surface to the highest point on the lateral malleolar arc, measured in the coronal and sagittal planes determined by the horizontal plane of the mid-trochlea.

³ The antero-posterior maximum distance on the articular surface for the lateral malleolus (Day & Wood, 1968).

⁴ Angle between the medial and lateral margins of the middle of the trochlea (Trinkaus, 1975b).

⁵ Angle between the long axis of the subtalar joint (midline across the medial and posterior calcaneal surfaces) and the median sagittal plane of the trochlea (Trinkaus, 1975b).

Table 18 Discrete trait features of the Gough's Cave 1 right talus.

Calcaneal surface fusion	partial anterior & medial ¹
Anterior extension of the medial malleolar surface ²	present
Medial extension of the trochlea	present
Lateral extension of the trochlea	present
Medial squatting facet	absent
Lateral squatting facet	present
Sulcus tali facet	absent
Sulcus tali margin rounding	present

¹ Partial fusion of the anterior and medial surfaces with a notch present along the sulcus tali margin (see Trinkaus, 1975a).

² For definitions of variations, see Barnett (1954) and Trinkaus (1975a).

Table 19 Osteometrics of the Gough's Cave 1 right cuboid.

Maximum length (M-1)	38.4
Medial length ¹	29.7
Lateral length (M-2)	13.5
Height ²	26.6
Calcaneal height ³	23.5
Calcaneal breadth ⁴	30.0
Navicular height	11.2
Navicular breadth	5.8
Lateral cuneiform height	17.3
Lateral cuneiform breadth	13.2
Metatarsal 4/5 height	19.3
Metatarsal 4/5 breadth	28.5
Metatarsal 4 height	19.3
Metatarsal 4 breadth	12.7
Metatarsal 5 height	14.5
Metatarsal 5 breadth	15.8

¹ Minimum distance on the medial side between the calcaneal and metatarsal 4 facets.

² Maximum dorso-plantar height of the bone.

³ All articular facet heights are the maximum dorso-plantar dimension of the articular facet in question.

⁴ Articular facet breadths are the maximum medio-lateral dimensions for the calcaneal and metatarsal facets and the maximum proximo-distal dimensions for the navicular and lateral cuneiform facets.

relatively long bone that is strongly narrowed laterally. An index comparing its maximum length to that of the talus provides a value of 69.8, which is exceeded only by that of Le Peyrat 5 (70.9) in a small 80% male sample of Mesolithic cuboid bones (62.8 ± 5.0 , $N = 5$). At the same time, its index of the lateral length to maximum (medial) length (35.2) is the lowest of the available Mesolithic indices (49.7 ± 8.3 , $N = 5$), again approached only by the one from Le Peyrat 5 (35.8).

The non-articular surfaces of the bone are quite porous, and the articular surfaces themselves have generally distinct but rounded margins. There is a large facet for the navicular bone, which is separated from the calcaneal facet by 2.0mm of non-articular bone and blends into the lateral cuneiform facet with only a modest angle in the subchondral bone surface. The metatarsal 4 and 5 facets are partially separated by a vertical ridge, with the metatarsal 5 facet being distinctly wider but shorter.

The peroneal sulcus exhibits a lateral projection for the tendon of *M. peroneus longus*, but its surface shows no evidence of an articulation with a sesamoid bone.

METATARSALS

Inventory

Metatarsal 1 Right (No. 1.1/33). Complete bone.

Metatarsal 3 Right (No. 1.1/32). Complete bone.

Metatarsal 4 Right (No. 1.1/31). Complete bone.

Morphology

The three preserved metatarsal bones of the Gough's Cave 1 right foot present an unexceptional morphology, with relatively smooth

surfaces and distinct articular facets. The metatarsal 1 presents a strongly twisted medial cuneiform facet and a large but smooth *M. peroneus longus* tubercle. Distally, it has a relatively flaring surface for the lateral sesamoid bone, and a clear lateral deviation of the head indicating hallux valgus.

Robusticity indices for the Gough's Cave 1 metatarsals (geometric mean of the midshaft diameters versus articular length) are similar to Mesolithic means for the first and fourth rays (metatarsal 1: 22.9 versus 23.0 ± 1.6 , $N = 5$; metatarsal 4: 12.9 versus 13.1 ± 0.7 , $N = 5$). The third metatarsal, however, has a robusticity index (12.2) which is two standard deviations below the mean of a Mesolithic comparative sample (13.4 ± 0.6 , $N = 5$).



Fig. 16 Plantar (above), medial (below left) and lateral (below right) views of the Gough's Cave 1 right metatarsals; $\times 1$.

Table 20 Length and midshaft diaphyseal measurements of the Gough's Cave 1 right metatarsals; in mm, unless otherwise noted.

	1	3	4
Maximum length	61.7	72.4	71.4
Articular length (M-1, M-2)	59.6	70.4	69.4
Midshaft height (M-4)	14.4	9.7	11.3
Midshaft breadth (M-3)	12.9	7.6	7.1
Total area (mm ²)	145.9	57.9	63.0
Cortical area (mm ²)	75.6	50.7	50.6
Medullary area (mm ²)	70.3	7.2	12.4
Dorso-plantar 2nd moment of area (I_y) (mm ⁴)	1438.1	331.0	472.1
Medio-lateral 2nd moment of area (I_x) (mm ⁴)	1174.9	207.2	193.7
Polar moment of area (mm ⁴)	2613.0	538.2	665.8

Table 21 Osteometrics of the Gough's Cave 1 right metatarsal epiphyses.

	1	3	4
Proximal maximum height (M-7)	30.1	21.0	19.0
Proximal maximum breadth (M-6)	21.6	14.3	13.1
Proximal articular height	30.1	20.7	18.6
Proximal articular breadth	16.8	13.6	11.9
Lateral cuneiform breadth ¹			2.3
Dorsal metatarsal 2 height ²		8.7	
Dorsal metatarsal 2 breadth		9.2	
Plantar metatarsal 2 height		8.4	
Plantar metatarsal 2 breadth		4.8	
Metatarsal 3 height			10.6
Metatarsal 3 breadth			11.0
Metatarsal 4 height		11.3	
Metatarsal 4 breadth		11.9	
Metatarsal 5 height			10.3
Metatarsal 5 breadth			11.3
Distal height (M-9)	22.8	15.5	14.4
Distal maximum breadth (M-8)	21.9	10.5	11.1
Distal articular breadth	20.2	9.8	9.4
Distal medial height ³	19.6		
Distal lateral height	20.9		
Torsion angle (M-11)	3°	14°	25°
Horizontal angle ⁴		16°	21°
Vertical angle ⁵		4°	15°
Horizontal head angle ⁶	7°		

¹Breadths of the secondary proximal metatarsal facets are all proximo-distal.

²Heights of the secondary proximal metatarsal facets are all dorso-plantar.

³Distal medial and lateral heights are from each hallucal sesamoid sulci to the dorsal margin of the metatarsal head.

⁴Angle between the coronal plane of the main metatarsal facet and the diaphyseal axis in the horizontal plane of the bone. A positive angle indicates a medial deviation of the facet.

⁵Angle between the coronal plane of the main metatarsal facet and the diaphyseal axis in the sagittal plane of the bone. A positive angle indicates a plantar deviation of the facet.

⁶Angle in the horizontal plane between the intersesamoid crest and the diaphyseal axis.

The relative lengths of the Gough's Cave 1 metatarsals can be assessed by comparing their articular lengths to talar length and femoral bicondylar length. In the first comparison, the first and third rays produce indices of 108.4 and 128.0, which are slightly shorter and longer respectively than the means of a Mesolithic sample (metatarsal 1: 113.6 ± 7.3 , $N = 5$; metatarsal 3: 122.9 ± 11.8 , $N = 5$). Comparing the same lengths to femoral length produces indices of 13.7 and 16.1, values which are similar to and slightly above the means of a Mesolithic sample (13.8 ± 0.8 , $N = 5$ and 15.6 ± 1.1 , $N = 5$ respectively).

SUMMARY

The lower limb remains of Gough's Cave 1 are therefore those of a largely average young adult male, compared to other European Mesolithic specimens. Overall diaphyseal robusticity is generally similar to that of other Mesolithic specimens, even though the fibula and third metatarsal appear relatively gracile. In general, however, musculo-ligamentous attachment areas are weakly marked, in terms of the prominence, size and rugosity of the various crests and tuberosities. The exceptions to this are the marked pilasters of the femora (but weak lineae asperae) and the large proximal tibio-fibular ligament crest on the right fibula.

The proximal femora and the femoral diaphyses exhibit a clear asymmetry, especially in their neck-shaft angles and diaphyseal dimensions. This asymmetry is accompanied, in the pelvis, by a greater degree of lateral flare of the left ilium. It is not possible to determine, given primarily preservation of only the right side below the knee, whether this asymmetry continued distally.

These aspects are associated with a pelvis that combines several distinctly male characteristics with an overall pelvic aperture shape which is female.

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